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Interactions among age, adiposity, bodyweight, lifestyle factors and sex steroid hormones in healthy Singaporean Chinese men

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Abstract

Aim: To examine the inter-relationships among age, lifestyle factors, anthropometric parameters, percent body fat and steroid hormone parameters in 531 healthy Singaporean Chinese men aged between 29 and 72 years old. **Methods:** Various lifestyle parameters were quantified through a survey, and testosterone (T), estradiol (E2), dehydroepiandrosterone sulphate (DHEAS) and sex hormone binding globulin (SHBG) were measured using established methods. Anthropometric parameters were collected and computed, and percent body fat (Siri) was measured using the DEXA scanner. **Results:** SHBG, DHEAS, bioavailable-T (Bio-T), E2, Siri, Ht, W/H, W/Ht and work stress were independently correlated with age. Using multivariate analyses and adjusting for age and other related factors, exercise, smoking and alcohol consumption have positive impacts on androgen levels and body composition. However, black and green tea consumption was associated with negative effects on body composition and with higher levels of E2 and Free Estradiol Index (FEI). Men with shorter sleep duration had significantly lower T levels as compared to those with 6 h or more of nightly sleep. Higher T levels were associated with lower levels of adiposity and other indices of adiposity, whereas higher E2 levels were related to higher levels of adiposity. Men with higher DHEAS were significantly taller and heavier than those with low DHEAS levels. **Conclusion:** The study showed the close interactions among the gonadal/adrenal and metabolic compartments, with age being a key determinant in their interactions. Lifestyle factors such as exercise, smoking, sleeping and alcohol and tea consumption might play significantly roles in determining the status of health in men. *(Asian J Androl 2007 Sep; 9: 611–621)*

Keywords: age; testosterone; sex hormone binding globulin; estradiol; dehydroepiandrosterone sulphate; bioavailable-testosterone; body fat; exercise; smoking; alcohol; tea; coffee; stress; sleep

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1 Introduction

It is well established that aging in men is associated with decreased androgen and increased sex hormone binding globulin (SHBG) production, resulting in a significant decline in free and bioavailable testosterone (Bio-T). This decline in androgen levels has been associated with a variety of pathological conditions, and has been termed late-onset hypogonadism (LOH) [1, 2]. However, the biochemical and pathophysiological characteristics of LOH remain ill-defined. In the hope of bringing some uniformity to the understanding of this condition in aging men, the International Society for the Study of Aging Men (ISSAM) has provided guidelines for the diagnosis and treatment of LOH [3].

Central in LOH is androgen deficiency in adult men. Although the physiological functions of T and its metabolites are well known, the physiological roles, if any, of estrogens in men are unclear. Studies have attributed some possible roles of estrogens in sexual, behavioral, bone, cardiovascular and other metabolic functions in men [4, 5]. As with estrogens, the role of dehydroepiandrosterone (DHEA) in men is unclear. Several studies have reported positive effects of DHEA on bone metabolism and body composition [6], but its effect on cognition remains controversial [7].

Apart from physiological parameters, many lifestyle factors influence the secretion of androgens in men [8–12]. Most studies of the relationships between serum sex steroid hormone levels and lifestyle factors have been carried out on white populations, with relatively few having been carried out among Asian populations.

From an ongoing study of the determinants of the aging process in Singaporean Chinese over the last 8 years, it was noted that age is a major determinant on the functionality of most health compartments. This impact of age on the various compartments occurs in an integrated manner. Therefore, the present study sought to examine the inter-relationships among age, lifestyle factors, bodyweight (Wt), adiposity and steroid hormone parameters, including T, estradiol (E2), dehydroepiandrosterone sulphate (DHEAS) and SHBG, bioavailable-T (BioT) and Free Estradiol Index (FEI) levels in a cohort of healthy Singaporean Chinese men. An understanding of how these factors are integrated in their effects on the various physiological compartments can assist in the formulation of a holistic modality for the management of aging men.

2 Materials and methods

2.1 Subjects

Institutional approval for the study was obtained and each volunteer gave his written informed consent. Ethnic differences exist and, therefore, only 531 Singaporean Chinese men aged between 29 and 72 years were included in this analysis. Subjects were recruited from the general public through an open invitation, first through an announcement during the World Congress in Sexology held in Singapore. The announcement was included in the major newspapers in Singapore. Continual recruitment was assisted through word of mouth from volunteer to volunteer. The targeted number of men between the ages of 30 to 70 years was 400. As the primary objective was to evaluate the determinants of the aging process, subjects who have or have had, and were treated for major illnesses were excluded from the study. Only subjects with no known existing or history of major medical illnesses, such as cancer, hypertension, thyroid dysfunction, diabetes, osteoporotic fracture and cardiovascular events, were included in the present study. Subjects were not paid for participation. They represent the diverse spectrum of the population in Singapore, and include those with low and high levels of education, working and non-working men (retirees), and men with various vocations (Table 1). These profiles are typical of Singapore, which is a highly urbanized city state with no rural population.

Each subject answered a questionnaire with questions regarding medical and dietary history, social circumstances, sex, family history of dyslipidemia and other relevant history regarding consumption of hormones, supplements and medication, types of beverages, cigarettes and alcohol.

2.2 Anthropometric measurements

Wt was measured without shoes using an electronic measuring scale, and height (Ht) was taken to the nearest centimeter. The body mass index (BMI) was calculated as bodyweight in kilograms divided by height in meter squared. Waist circumference (W) was measured midway between the lower costal margin and iliac crest during the end-expiratory phase [13]. Hip circumference (H) was measured in centimeters. In addition, the waist/hip (W/H) and waist/height (W/Ht) ratios were computed as indices of body fat. The comparative usefulness of these anthropometric measures as indices for body fat is reported in an earlier study [14].

2.3 Body composition

Dual-energy X-ray absorptiometry (DEXA) was used for the estimation of the percent body fat, a technique that correlates well with other methods, including hydrodensitometry and Jackson and Pollock (7-site) skinfold prediction [15]. Each subject underwent a whole body scan using DEXA (DPX-L, Lunar Radiation, Madison, WI, USA; software version 1.3z). Percent body fat was computed automatically by the DEXA scanner using Siri formula-calculation (Siri) [16].

2.4 Aerobic and impact exercise scores

From the survey, the type, duration and frequency of exercise for each individual were used to derive the total impact exercise (ImpSc) and total aerobic exercise (AeroSc) scores. Each exercise type was given both an aerobic and impact score from a scale of 0 to 3, with 3 being the maximum score. Aerobic exercises are those that raise the heart rate above normal, whereas impact exercises are those that involve weight-bearing, including that of bodyweight or additional external weight, such as in weight lifting. Only an exercise of at least 20 min duration each time was given a score and the total score reflected the amount of exercise in a week. For example, jogging for at least 20 min was given a score of 3 for aerobic and 3 for impact. If an individual jogged five times a week, his total aerobic score would be 3 × 5 = 15 and impact score 3 × 5 = 15. In contrast, lap-swimming for 30 min, five times a week was given a total aerobic score of 3 × 5 = 15, but an impact score of 0 × 5 = 0. Therefore, the total impact score (ImpSc) and aerobic score (AeroSc) for each individual per week is 21. The range of exercises and their scores are depicted in the Table 2.

2.5 Surveys for work stress and sleep duration

In the general questionnaire, subjects were asked to rate their perception of the work stress and duration of sleep each night and other lifestyle factors. See Table 3 for the source of scores.

2.6 Hormonal assays for total T, E2 and DHEAS

Serum T and E2 concentrations were measured using reagents and method recommended by the World Health Organization Matched Reagent Program [17] with modification to the scintillation proximity methods established in-house [18]. However, DHEAS and SHBG were measured by established radioimmunoassay methods reported earlier [19]. The intra- and inter-assay coefficients of variation were less than 10% over the effective

Table 1. Demographic parameters.

Marital status (%)	Married/with partner (88.6)	Divorced/widowed (3.4)	Singles (8.0)		
Education (%)	Primary (2.3)	Secondary (30.3)	Junior college (14.9)	Tertiary (525)	
Employment (%)	Retired (17.2)	Full-time (71.9)	Part-time (5.7)	Not working (5.2)	
Occupation (%)	Executive (23.7)	Professional (43.7)	Admin/Service/Technical (32.6)		
Income/month (%)	< $ 1 K (4.6)	$ 1–3 K (24.1)	$ 3–5 K (36.2)	$ 5–10 K (26.4)	> $ 10 K (8.7)

Table 2. Impact (ImpSc) and aerobic (AeroSc) scoring for different exercises.

Scores	Impact exercises of > 20 min	Aerobic exercises of > 20 min
1	Causal walking, Tai-Chi, hiking, stepping and skiing exercises in the gym, roller-blading, ice-skating	Leisure swimming, walking, Tai-Chi
2	Brisk-walking, line and ballroom dancing	Brisk walking, line and ballroom dancing, long distance cycling, lapping in swimming, moderate rate on an easy rider
3	Jogging, running, weight lifting, soccer, football, badminton, table-tennis, other ball games which involve running and martial arts of vigorous forms	Jogging, running, soccer, football, badminton, table-tennis, other ball games which involve running, competitive swimming, stepping and skiing exercises in the gym, roller-blading and ice-skating

Table 3. Scoring system.

Level of work stress	Score
No stress at work (no stress)	0
Feeling of stress: infrequent/rare (low stress)	1
Feeling of stress: moderately frequent/seasonal (moderate)	2
Unbearable/about to breakdown (high)	3
Sleep duration per night	Score
< 4 h	1
≥ 4 h	2
≥ 6 h	3
> 8 h	4
Consumption of coffee, black or green tea	Score
No	1
Yes (at least 1 cup/day)	2
Alcohol consumption or smoking	Score
No	1
Yes	2

concentration ranges for T and DHEAS and less than 15% for E2 and SHBG.

2.7 Method of calculation of BioT

BioT was calculated using the computer formula of Vermeulen, which is available on the ISSAM website (www.issam.ch). Total T was computed as ng/dL, whereas that for SHBG as nmol/L. Albumin level was assumed to be 44. Hence, BioT was expressed as ng/dL [20].

2.8 Method of calculation of FEI

SHBG is an important factor in defining estrogen action. Because a method for direct measurement of free estradiol levels using equilibrium dialyses is not well established, the calculated FEI was used as an index of estrogen action to take into consideration changes to E2 and SHBG levels. Based on the formula established for the calculation of free androgen index (FAI) [21], FEI is calculated as follows:

$$FEI = \{E2\ (nmol/L)/SHBG\ (nmol/L)\} \times 1\,000.$$

2.9 Statistical analysis

Statistical analyses were performed using SPSS for Windows version 15 (SPSS Inc., IL, USA). Basic descriptive statistics, linear regression, Spearman and Pearson bivariate correlation and multivariate analyses were used where appropriate.

3 Results

Using Pearson's and Spearman's correlation, age was the single most important determinant of many of the biological and lifestyle factors studied. It was significantly ($P < 0.05$) correlated with SHBG, E2, W/H, W/Ht, W, ImpSc, AeroSc, and number of cups of green tea per day, with r-values ranging from 0.094 to 0.292. Age was significantly ($P < 0.05$) and negatively correlated with Bio-T, DHEAS, FEI, H, Wt, Ht, work stress and sleep duration, with r-values ranging from –0.090 to –0.369.

Adjusting for BMI, multivariate analyses showed that only DHEAS, SHBG, BioT and E2 were independently correlated with age (Table 4). Among the anthropometric and lifestyle factors only Ht, W/H, W/Ht and Siri fat were independently related with age (Table 4).

To evaluate the interactions among steroid hormone parameters, lifestyle factors and indices for bodyweight and adiposity, multivariate analyses with adjustments for age and BMI and other related variables were carried out. Both steroid hormone parameters and indices for

Table 4. Steroid hormonal, anthropometric and lifestyle factors based on age groups. [a]Estradiol (E2) levels in group 1 (Gp1) were significantly lower than those in Gp3 (P = 0.043). [b]Dehydroepiandrosterone sulphate (DHEAS) in Gps 1 and 2 were significantly higher than those in Gps 3 and 4 ($P < 10^{-4}$), Gp3 levels were higher than Gp4 (P = 0.016). [c]Sex hormone binding globulin (SHBG) levels in Gps 1 and 2 were significantly lower than those in Gps 3 and 4 (P < 0.005). [d]Bioavailable-testosterone (Bio-T) levels in Gp1 were significantly higher than those in Gps 3 and 4 (P = 0.04), levels in Gp2 were higher than Gp3 (P = 0.026). [e]Siri fat levels in Gp1 were significantly lower than those in Gp3 (P = 0.023). [f]Height (Ht) in Gp1 was significantly higher than those in Gp4 (P = 0.011). [g]Waist/hip (W/H) in Gps 1 and 2 were significantly lower than those in Gps 3 and 4 (P < 0.002), W/H in Gp3 was significantly lower than those in Gp4 (P = 0.026). [h]Waist/height (W/Ht) levels in Gps 1 and 2 were significantly lower than those in Gps 3 and 4 (P < 0.003). [i]Work stress levels in Gps 1, 2 and 3 were significantly higher than those in Gp4 (P < 0.005).

Age groups (*n*) / Parameters	Gp1 (71) (< 40 years)	Gp2 (200) (41–50 years)	Gp3 (179) (51–60 years)	Gp4 (81) (> 60 years)
E2 (pg/mL)[a]	29.30 ± 1.70	33.50 ± 0.99	35.10 ± 1.07	33.70 ± 1.68
DHEAS (ng/mL)[b]	3053 ± 134	2706 ± 76	2215 ± 82	1752 ± 129
SHBG (nmol/L)[c]	26.70 ± 1.30	27.60 ± 0.73	32.00 ± 0.78	33.40 ± 1.20
Bio-T (ng/mL)[d]	304.0 ± 14.0	286.0 ± 8.0	252.0 ± 8.7	251.0 ± 13.7
Siri fat (%)[e]	16.40 ± 0.66	17.70 ± 0.34	18.60 ± 0.36	17.10 ± 0.53
Ht (cm)[f]	170.40 ± 8.00	169.50 ± 0.42	167.60 ± 0.43	166.60 ± 0.65
W/H[g]	0.861 ± 0.006	0.875 ± 0.003	0.892 ± 0.003	0.909 ± 0.005
W/Ht[h]	0.487 ± 0.005	0.494 ± 0.003	0.510 ± 0.003	0.514 ± 0.004
Work stress[i]	1.830 ± 0.092	1.620 ± 0.051	1.590 ± 0.063	1.12 ± 0.12

bodyweight and adiposity were collectively input as dependent factors in these analyses. Fixed factors in the analyses included sleep duration groups (SlpD-Gps), work stress groups (WkStress-Gps), T groups (T-Gps), BioT groups (BioT-Gps), E2 groups (E2-Gps), SHBG groups (SHBG-Gps), aerobic exercise (Aero-Gps) and impact exercise groups (Imp-Gps), alcohol, coffee, tea and green tea consumption, and smoking groups.

Both steroid hormone parameters and indices of bodyweight and adiposity were affected by some of the lifestyle factors studied. Serum T levels were significantly lower, by approximately 28%, in men with shorter duration (< 4 h) of nightly sleep when compared to those with at least 6 h of sleep (Table 5). This observed difference cannot be accounted for by other demographic factors as there were no significant differences in age, working status, educational and income levels between the two groups.

Impact and aerobic exercise had similar effects on various parameters, except that aerobic exercise significantly affected T levels, whereas impact exercise affected FEI levels in men (Table 6). High intensity of both impact and aerobic exercises (exercising for at least four times a week and a total score of > 12; Gp3 significantly lowered the percent body fat (Siri) and W/H ratio (Table 6). Those with high ImpSc (> 12) had significantly higher SHBG levels, which resulted in significant decreases in FEI (Table 6). However, moderate to high aerobic exercises (Gp2 and Gp3) resulted in higher T levels when compared to those with no or low intensity of exercise (Table 6).

Among the cohort of Singaporean Chinese men studied, only 8.7% smoke with a daily average of 13 cigarettes. Among the men studied, 62.5%, 31.6% and 12.1%, respectively, drink coffee, black tea and green tea daily. Among those who drink coffee, black or green tea, more than 70% drink 1–2 cups per day. Only 34.1% of the Singaporean Chinese men consume alcohol. Among these men, the majority either drink wine and/or beer. More than 80% drink wine or beer on a daily basis. However, approximately 15% consume hard liquor, with this normally occurring during birthday or wedding celebrations.

Because exercises significantly impact steroid hormone and anthropometric parameters, the effects of smoking, alcohol, coffee, black and green tea consumption were evaluated with exercise scores as covariates. Whereas coffee consumption was not associated with any change in steroid hormone parameters or indices for bodyweight and adiposity, smoking, black or green tea and alcohol consumption were associated with significant changes (Table 7). Interestingly, men who smoked had significantly higher levels of T and Bio-T levels, while

Table 5. Testosterone (T) levels in various sleep duration groups. All values were adjusted for age and body mass index. †T levels in < 4 h group were significantly lower than those in 6–8 h and > 8 h groups ($P < 0.050$). SlpD-Gps, sleep duration groups.

SlpD-Gps (*n*)	< 4 h (13)	4–6 h (75)	6–8 h (337)	> 8 h (80)
T (mean + SE [ng/mL])	3.72 ± 0.52†	4.71 ± 0.22	5.19 ± 0.11	5.17 ± 0.21

Table 6. Effects of intensity of impact and aerobic exercises on various parameters. Values were adjusted for age and body mass index. [a]Levels in Gp3 were significantly lower than corresponding levels in Gp1 and Gp2 ($P < 0.002$). [b]Levels in Gp3 were significantly lower than corresponding levels in Gp1 ($P < 0.035$). [c]Levels in Gp1 were significantly lower than corresponding levels in Gp2 and Gp3 ($P < 0.05$). [d]Levels in Gp1 were significantly lower than corresponding levels in Gp3 ($P = 0.006$). [e]Levels in Gp1 were significantly higher than corresponding levels in Gp3 ($P = 0.043$). Aero-Gps, aerobic exercise groups; Imp-Gps, impact exercise groups; FEI, Free Estradiol Index; SHBG, sex hormone binding globulin; T, testosterone; W/H, waist/hip.

Parameters / AeroSc-Gps (*n*)	Siri (%)	W/H	SHBG (nmol/L)	T (ng/mL)
Gp1 (282)	18.30 ± 0.30	0.889 ± 0.003	28.50 ± 0.68[c]	4.85 ± 0.68[c]
Gp2 (190)	18.10 ± 0.35	0.884 ± 0.003	31.10 ± 0.80	5.29 ± 0.14
Gp3 (59)	15.40 ± 0.64[a]	0.872 ± 0.006[b]	32.90 ± 1.46	5.52 ± 0.26
Parameters / ImpSc-Gps (*n*)	**Siri (%)**	**W/H**	**SHBG (nmol/L)**	**FEI**
Gp1 (307)	18.40 ± 0.29	0.890 ± 0.003	28.90 ± 0.65[d]	4.88 ± 0.16[e]
Gp2 (171)	18.00 ± 0.37	0.882 ± 0.003	30.60 ± 0.84	4.51 ± 0.21
Gp3 (53)	14.90 ± 0.66[a]	0.871 ± 0.006[b]	34.00 ± 1.50	3.88 ± 0.37

at the same time had reduced levels of adiposity (Siri fat) when compared with men who did not smoke (Table 7). Similarly, alcohol consumption was associated with increased Bio-T and decreased Siri (Table 7). Green tea consumption was associated with significantly higher bodyweight, BMI and hip circumference (H), whereas men who consumed black tea had significantly higher levels of E2 and FEI when compared to those who did not consume tea (Table 7).

Being stressed at work is a common problem among the Singaporean work force. The drive to be successful in a very competitive urban society like Singapore is very high, especially among the ethnic Chinese. More than 65% of those in this cohort of Singaporean Chinese men who were working had from moderate to high levels of work stress (Groups 2 and 3). Table 8 shows that the higher the level of work stress, the higher the degree of adiposity, as reflected in the higher waist circumference (W) and W/H and W/Ht ratio.

Tables 9–12 reflect changes in anthropometric parameters and adiposity based on T-Gps, SHBG-Gps, E2-Gps and DHEAS-Gps. The groupings were based on mean + standard deviation (SD), with Gp1 having levels in the first quartile (< [mean – SD]), and Gp3 in the fourth quartile (> [mean + SD]). The results showed that T and SHBG had independent and similar effects on indices of bodyweight and adiposity. Low T levels were associated with significantly higher BMI, W, H, W/Ht and Siri fat (Table 9). Low SHBG levels had similar effects as low T levels except that low SHBG levels were not associated with any significant changes in Siri (Table 10). High E2 levels had the opposite effects of high T and SHBG levels. Men with higher E2 levels were associated with higher degrees of adiposity, as indicated by higher W/H ratio (Table 11). Higher levels of DHEAS were significantly associated with taller (Ht) and heavier (Wt) men (Table 12).

4 Discussion

Age and some lifestyle factors are associated with changes in steroid hormone levels and a wide range of clinical problems, and may detrimentally affect wellness in life [8–12, 22]. Although the effects of T and E2 on sexual function and some other health indicators have been well established, relatively few studies have been

Table 7. Effects of smoking, green tea, tea, and alcohol consumption on steroid hormones, anthropometric parameters and Siri. Values were adjusted for age, exercise scores and body mass index. *P*-values denote the comparisons between the No and Yes groups. BMI, body mass index; Bio-T, bioavailable-testosterone; E2, Estradiol; FEI, Free Estradiol Index; H, hip; T, testosterone; Wt, weight.

Parameters / Smoking (*n*)	T (ng/mL)	Bio-T (ng/dL)	Siri (%)
No (484)	5.030 ± 0.090	268.0 ± 5.5	18.10 ± 0.19
Yes (46)	5.730 ± 0.290	306.0 ± 17.6	15.80 ± 0.62
P-values	0.022	0.044	0.001
Parameters / Green tea (*n*)	**Wt (Kg)**	**BMI (Kg/m^2)**	**H (cm)**
No (443)	67.50 ± 0.46	23.80 ± 0.14	95.30 ± 0.26
Yes (64)	70.90 ± 1.28	24.70 ± 0.39	97.30 ± 0.74
P-values	0.010	0.030	0.012
Parameters / Tea (*n*)	**E2 (pg/mL)**	**FEI**	
No (339)	32.70 ± 0.79	4.47 ± 0.15	
Yes (168)	35.60 ± 1.10	5.01 ± 0.20	
P-values	0.032	0.031	
Parameters / Alcohol	**Bio-T (ng/dL)**	**Siri (%)**	
No (349)	262.0 ± 6.5	18.10 ± 0.23	
Yes (181)	289.0 ± 8.6	17.40 ± 0.31	
P-values	0.015	0.049	

Table 8. Effects of work stress on anthropometric parameters. Data were adjusted for age, exercise scores and body mass index.

Parameters / Wkstress-Gps (*n*)	Waist (cm)	W/H	W/Ht
Gp0 (39)	85.70 ± 1.10	0.894 ± 0.007	0.508 ± 0.007
Gp1 (92)	84.70 ± 0.72	0.882 ± 0.005	0.503 ± 0.004
Gp2 (250)	83.90 ± 0.42	0.880 ± 0.003	0.498 ± 0.003
Gp3 (13)	89.90 ± 1.45	0.925 ± 0.011	0.529 ± 0.010
P-values	Gp1 *vs*. Gp3 (0.036)	Gps1 and 2 *vs*. Gp3 (0.012, 0.012)	Gp2 *vs*. Gp3 (0.022)

Table 9. Changes in anthropometric parameters and adiposity based on different testosterone (T) groups. All values were adjusted for age, exercise, sex hormone binding globulin (SHBG) and Free Estradiol Index (FEI). †Levels in Gp1 were significantly higher than corresponding levels in Gp2 (< 0.035). ‡Levels in Gp1 were significantly higher than corresponding levels in Gp2 and Gp3 (< 0.035). BMI, body mass index.

T groups (*n*)	Gp1 (79)	Gp2 (382)	Gp3 (68)
BMI (Kg/m^2)	24.70 ± 0.33†	23.80 ± 0.14	23.60 ± 0.37
Waist (cm)	87.10 ± 0.78‡	84.20 ± 0.34	83.80 ± 0.88
Hip (cm)	97.10 ± 0.64†	95.30 ± 0.28	95.10 ± 0.72
Waist/Height	0.520 ± 0.002‡	0.500 ± 0.002	0.500 ± 0.005
Siri (%)	19.30 ± 0.56‡	17.70 ± 0.24	17.00 ± 0.63

Table 10. Changes in anthropometric parameters and adiposity based on different SHBG groups. All values were adjusted for age, exercise, testosterone (T) and Free Estradiol Index (FEI). †Levels in Gp3 were significantly lower than corresponding levels in Gp1 and Gp2 (< 0.05). ‡Values in Gp1were significantly higher than corresponding values in Gp3 (< 0.035). BMI, body mass index; Wt, bodyweight.

SHBG groups (*n*)	Gp1 (63)	Gp2 (378)	Gp3 (78)
Wt (Kg)	69.70 ± 1.24	68.20 ± 0.51	65.20 ± 1.10†
BMI (Kg/m^2)	24.50 ± 0.37‡	24.00 ± 0.15	23.10 ± 0.33
Waist (cm)	86.50 ± 0.88	84.70 ± 0.33	82.60 ± 0.78†
Waist/height	0.514 ± 0.005‡	0.503 ± 0.002	0.493 ± 0.005

Table 11. Changes in Waist/height (W/Ht) based on different estradiol (E2) groups. All values were adjusted for age, and body mass index (BMI). †Values in Gp1 were significantly lower than corresponding values in Gp2 (P = 0.04).

E2 groups (*n*)	Gp1 (110)	Gp2 (330)	Gp3 (79)
Waist/Hip	0.876 ± 0.004†	0.888 ± 0.002	0.889 ± 0.005

Table 12. Changes in height based on different dehydroepiandrosterone sulphate (DHEAS) groups. All values were adjusted for age. †Values in Gp3 were significantly higher than corresponding values in Gp2 (P < 0.02).

DHEAS groups (*n*)	Gp1 (81)	Gp2 (342)	Gp3 (85)
Height (cm)	168.60 ± 0.67	168.00 ± 0.32	170.30 ± 0.70†
Weight (Kg)	69.0 ± 1.0	67.0 ± 0.5	70.5 ± 1.1†

carried out to define the role of DHEA in sexual and health functions. A recent report from the Massachusetts Male Aging Study (MMAS), however, found a relationship between DHEA and several diseases, including coronary heart disease, and sexual dysfunction, and general physical and mental wellbeing [23].

In agreement with several previous studies, levels of DHEA and BioT in Singaporean Chinese men declined significantly, whereas those for SHBG and E2 increased significantly with age [1, 9, 11, 12, 23]. Increase in adiposity with age was reflected by significant increases in W/H, W/Ht and Siri. Interestingly, height in Singaporean Chinese men showed an age-associated decline and might be related to significant decrease in total bone mineral content (Goh *et al.*, unreported data). Significantly more men in the younger age group have higher levels of work stress than men in the older age groups. This could be a reflection of the highly competitive society in highly urbanized Singapore and is congruent with our earlier finding that Singaporeans are highly stressed to the extent that had affected their sexual functions [24].

Different steroid hormone levels were related to changes in anthropometric parameters and Siri studied. As shown in many studies [23, 24], men with low testosterone levels (< 3.30 ng/mL) have significantly higher bodyweight (8.3%) and BMI (8.7%) when compared with men with higher T (> 7.10 ng/mL). At the same time, the levels of adiposity were comparatively higher as reflected by an 18.8% increase in Siri, and increases ranging from 2.9% to 6.9% of W, H, W/H and W/Ht. As SHBG and T levels were significantly correlated, lower levels of SHBG had similar effects on bodyweight and the levels of adiposity in men when compared to those with higher levels of SHBG.

E2 showed the opposite effect of adiposity from T. Men with high E2 levels had significantly higher adiposity, as reflected by higher W/H.

Among the steroid hormones studied, only DHEAS was associated with changes in Ht and Wt. Men with higher DHEAS were significantly taller and heavier. Because DHEAS decreased significantly with age, the decrease in weight and height might be related to decreases in DHEAS.

The results showed close interactions between the gonadal/adrenal axes and the metabolic compartments. They showed the opposing effects of T and E2 on bodyweight and adiposity and the apparent direct correlation of bodyweight and height to DHEAS. These results give further support to the suggestion that men with LOH are associated with obesity [25].

Among Singaporean Chinese men, smoking and alcohol consumption accounted for 8.7% and 34.2%, respectively. In addition, the rate of smoking was approximately 13 cigarettes per day, while most of those who consume alcohol drink beer and wine, with an average of 1 to 2 glasses a day. Men who smoked had significantly higher T and Bio-T, by approximately 14%, when compared to non-smokers. At the same time, the percent body fat (Siri) was 2.3% lower than in non-smokers. These findings were similar to those in earlier studies [1, 11, 12] and in contrast to another study [9]. The reason for the conflicting results might be related to the intensity of smoking noted in different study populations. Because these data were adjusted, the differences noted cannot be accounted for by age alone. However, the exact mechanism of these apparent beneficial effects of smoking and alcohol consumption on androgen levels and adiposity is not known and warrants further in-depth studies in the near future.

Although drinking coffee did not, drinking black or green tea caused significant changes in some of the steroid hormonal and anthropometric parameters. Drinking black tea led to significant increases in E2 and FEI levels, whereas drinking green tea resulted in increases in bodyweight, BMI and hip circumferences. Higher levels of E2 levels are associated with higher levels of adiposity. Therefore, drinking either black or green tea appears to increase the risk of obesity in Chinese men. This was an unexpected finding and it would be intriguing to evaluate the mechanism through which black and green tea can cause such an increase.

Both impact and aerobic exercises affect some steroid hormonal and anthropometric parameters in Chinese men. When compared to men without or with low intensity (Gp1), men performing higher intensity aerobic exercises (Gp3) had higher T (13.8%) and SHBG (15.4%) levels. Higher levels of T were associated with beneficial reduction of the level of adiposity, as reflected in decreases in Siri and W/H of 11.9% and 3.8%, respectively. Likewise, high intensity of impact exercises had raised SHBG levels (by 17.6%) to such an extent that had caused significant reduction of FEI (by 20.5%). Reduction in FEI is beneficial and had, in turn, probably caused a significant reduction in the level of adiposity. As with increased T levels, men performing high intensity impact exercises (Gp3) had 19.0% and 2.1% lower Siri and W/H, respectively, when compared to those who did little or no exercise. Our observations were in agreement with other studies [4, 7, 23], and in contrast to others [1, 12]. Clearly, exercise and steroid hormone levels are interrelated with each other and in their effects on bodyweight and the degree of adiposity. Therefore, it is possible that the exercise-induced changes in bodyweight and adiposity might occur because of changes in T, SHBG and E2 levels. The results in the present study confirm the beneficial effects of exercises in reducing the degree of adiposity and obesity among the population. On average, Singaporean Chinese men, in their highly urbanized setting, do not exercise enough. Only approximately 10% of men had total exercise scores of > 12, an intensity of exercise that resulted in the observed beneficial effects. In addition, those in the younger age groups of < 45 years in particular, do not exercise enough. In the Singaporean context, this is because of their preoccupation with establishing their careers and raising young families. More creative campaigns to get these men to participate in regular exercise are needed to mitigate the ill effects of a sedentary lifestyle among men in Singapore, and to combat the rising trend of obesity in Singapore.

Although BMI has been established as an index of bodyweight, it is frequently used as an index of adiposity. As was shown from results of an earlier study [14], BMI, H, W, W/H and W/Ht are highly correlated with each other and with percent body fat (Siri). However, there are limitations of these anthropometric parameters as indices of adiposity [14]. BMI is more appropriately viewed as a weight rather than an adiposity index [14]. The fundamental difference of Siri as an index of adiposity as opposed to BMI as a bodyweight index was demonstrated in the effects of steroid hormones on these two indices. T had greater impact on adiposity than on bodyweight. When comparing Siri and BMI in high T versus low T groups, men with low T had significantly higher Siri (by 13.6%); correspondingly, BMI was higher by only 4.7%. Higher levels of SHBG, which is produced by the liver, were associated with lower BMI but not Siri.

Amount of sleep has often been neglected in studying the impact of lifestyle factors on sex steroid hormones levels. Older men tend to sleep less than younger men, as demonstrated in the present study. After adjusting for age, men who slept for less than 4 h nightly had significantly lower T levels, by 28.2% when compared to those who slept for > 6 h nightly. Those who slept for between 4 h and 6h had reduced T, by approximately 9%. This is an important lifestyle parameter and should be targeted for lifestyle modification to improve the health status of the population. Increased work demands disrupt sleep. This, in turn, might have long term damaging effects on health. Education regarding the importance of adequate sleep is another key strategy for helping the population to age healthily and, thereby, reduce the risk of illness.

Results from the present study showed the close interactions between the gonadal/adrenal and the metabolic compartments. Promotion of regular and sufficiently intense exercise and sufficient sleep are key lifestyle modifications that can help to improve the health of the population. Some observations warrant further research. Of particular interest is the observation that smoking and alcohol consumption positively affect androgen levels and body composition, whereas black and green tea consumption negatively impact body composition.

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